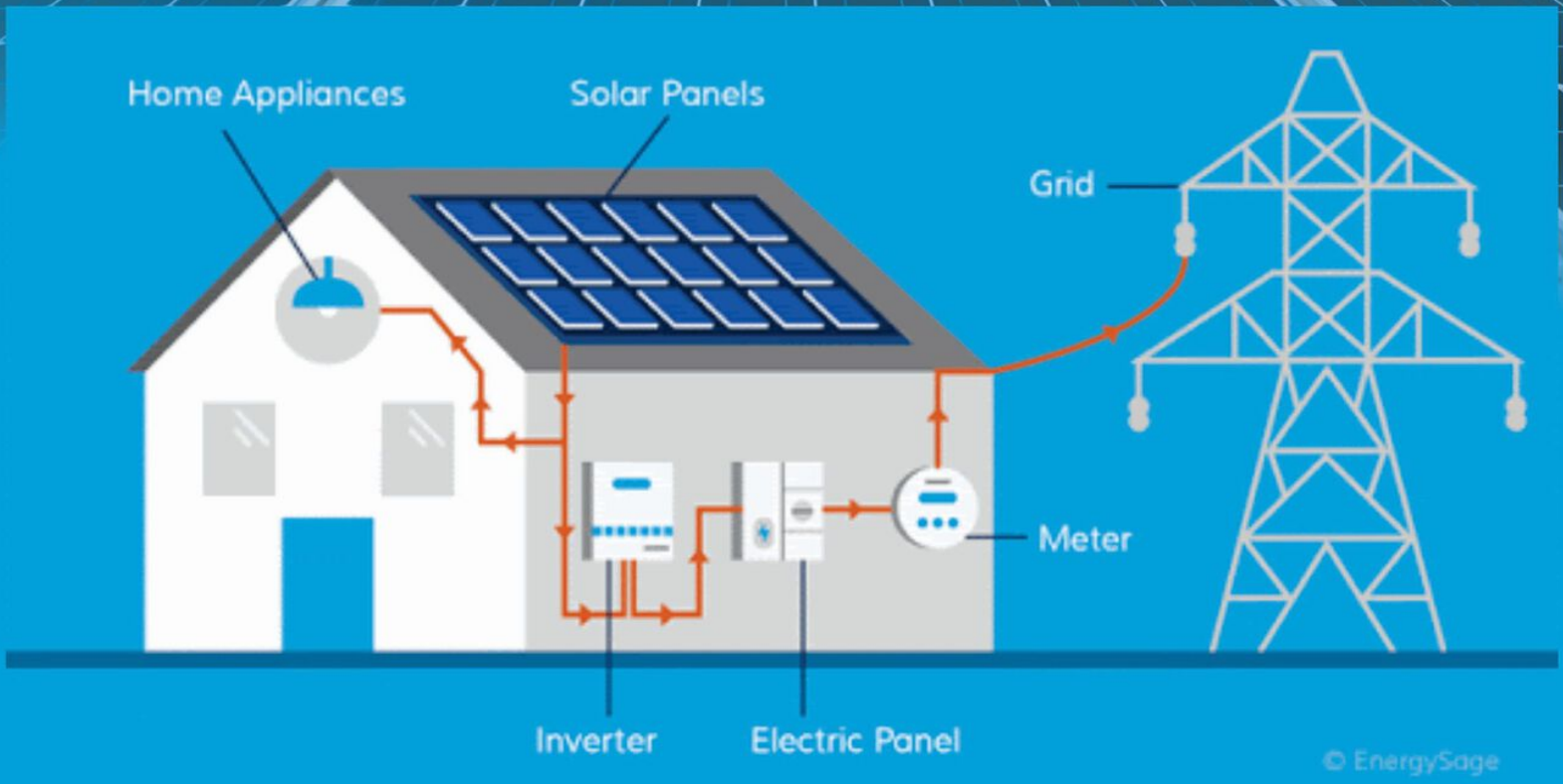
SOLAR POWER FOR BEGINNERS

The Ultimate Guide on Mastering the Basics, Designs, and Installations of Solar Power Systems



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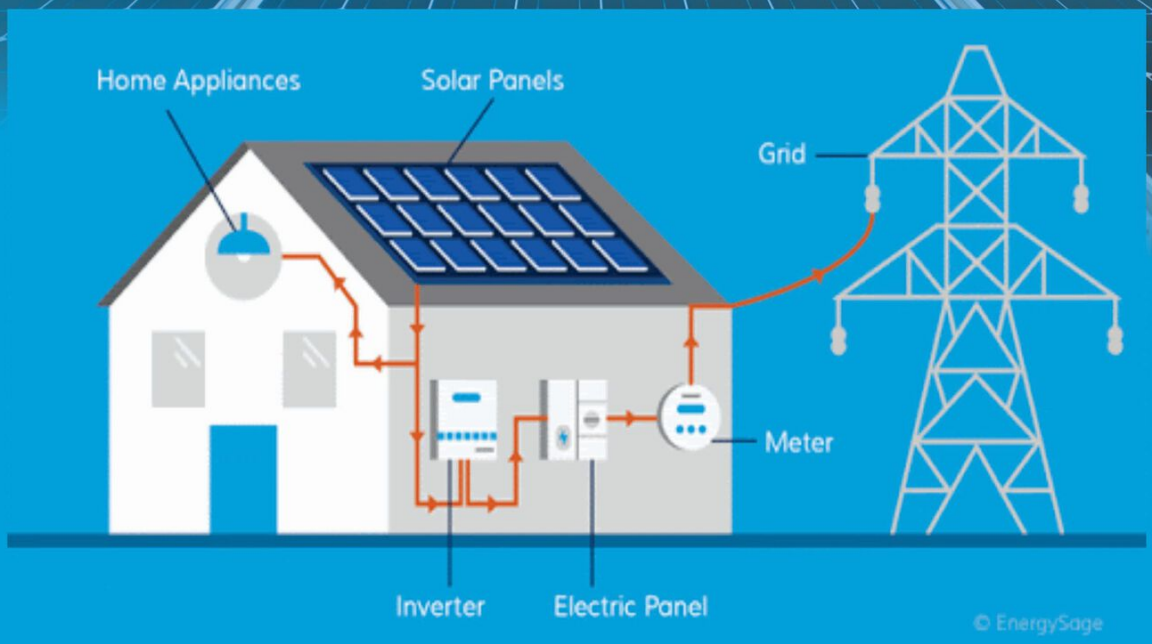

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INTRODUCTION

The Solar Power system in a home is a valuable asset that increases a home's value and reduces potential energy costs every month. Investing in solar is a huge investment that can minimize your net worth to about twenty-eight percent or higher; although, the cost of purchase and installation could be frightening.

Determining solar installations' total cost is best done using the average monthly energy consumption in your home. This is often printed on your regular utility bills. You will also estimate the size of the solar array that can produce such an amount of energy in your home.

Most homeowners opt for solar systems due to the rising cost of conventional electricity sources from the general grid. This book will help you to know the systematic processes of customizing your solar power stations in the home.

Also, you will know various terminologies associated with solar power installations in a simple and understandable manner. This is an environmental-friendly system that gives you access to constant energy. You can share this natural endowment with friends and neighbors and export excess solar power in our home to the typical grid. Then, you will be paid the feed-in tariff.

CHAPTER ONE

The Basic Terms in Solar Power Systems

A proper understanding of some basic terms in the solar power system will help you know your solar installations' features. These terminologies include

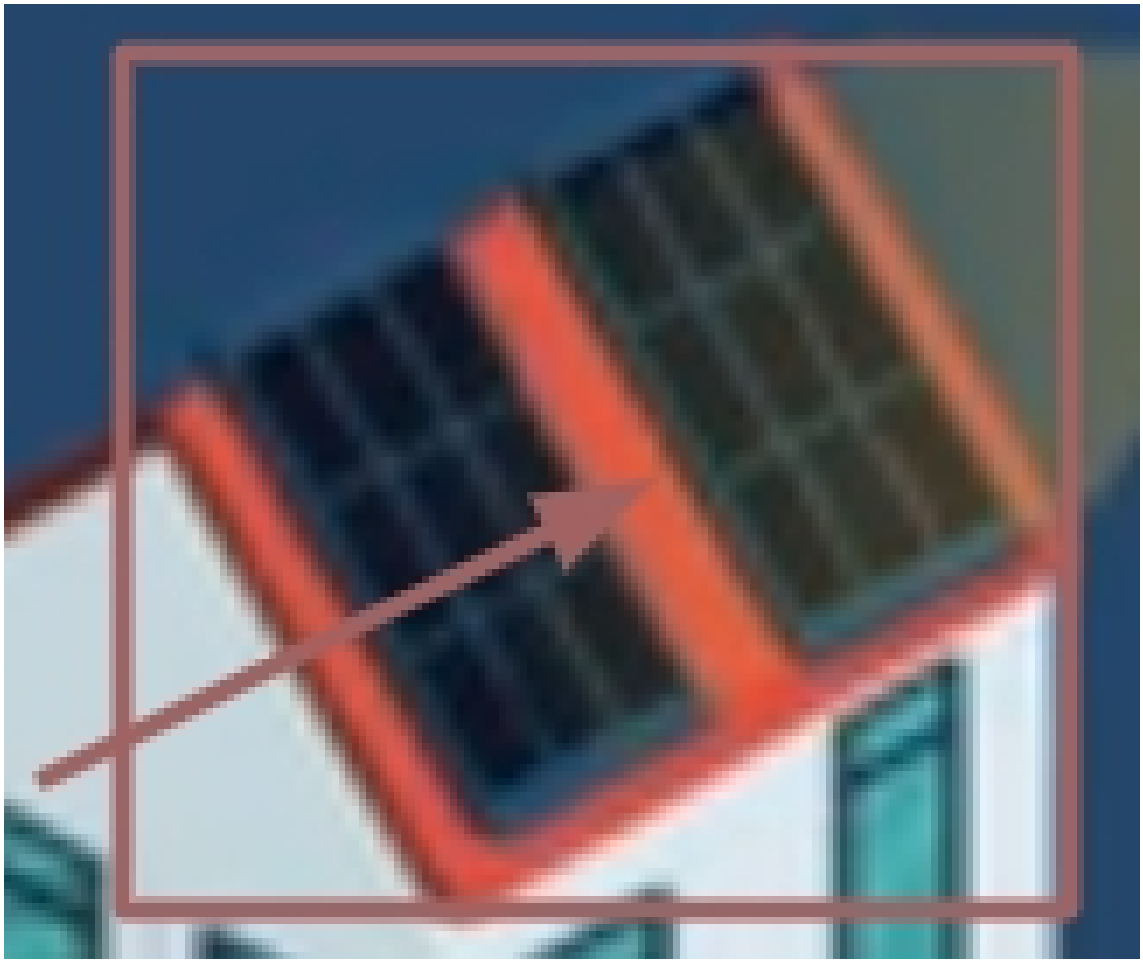
- Ampere (Amp) – the current flow unit is the unit of electric current corresponding to a certain number of electrons crossing a fixed point every second.
- Azimuth – an angle measured horizontally in degrees in a clockwise direction from a reference point. It is usually the north or south axis of the horizon. It also gets to the point of intersection by the object's line of elevation.
- Electric current – the rate of flow of electricity calculated in Amperes.
- Albedo – is the degree of light reflection from a surface.
- Cell – the primary unit of a PV panel.
- Altitude – the elevation of the sun over the horizon.
- Direct current (DC) – the flow of electric currents only in a particular direction.
- Direct insolation – the radiation of the solar system on the earth's surface.
- Electrical efficiency – electricity output divided by the total electricity consumption.
- Array - interconnected photovoltaic modules providing a uniform electrical output.
- Electric circuit – an electrical path for current, generators, capacitors, and resistors.
- Alternating current (AC) – an electric current reversing its direction regularly.
- Diffuse insolation – the reflection or scattering of solar radiation by clouds, dust, and other atmospheric elements.

- Load – the act of including a device that absorbs power to an electrical circuit. It also means a device that absorbs power such as a bulb, refrigerator, television, etc. Another meaning of load in an electrical system is the energy consumption within an electrical circuit.
- Energy – sources of useful and usable power such as solar power, electricity, and fossil fuel.
- Electrical grid – an interconnection of electrical systems for proper electricity distribution.
- Inverter – an instrument capable of converting direct current (DC) into alternating current (AC).
- Kilowatt – 1,000 watts.
- Megawatt – 1,000,000 watts.
- Gigawatt (GW) – this amounts to 1,000,000, 000 watts.
- Ohm – a measurement of electrical resistance.
- Junction box – an enclosed space for electrical wires and installations.
- Insolation – the amount of solar energy received over an area within a specified period.
- Module – means a panel or an interconnection of solar cells.
- Photovoltaic (PV) – the conversion of radiation energy into electrical energy using solar cells.
- Silicon – an element for making semiconductors.
- Radiance or Solar Radiance – light from the sun.
- Remote system – a solar system that is not connected to the utility grid.
- Polycrystalline cell – solar cells generated from processed liquid silicon. Silicon crystals are produced in multiple forms during the solidification process, although it is not very efficient as monocrystalline cells.
- Solar – the capability to provide solar power. It also means generated by energy from the sun.
- Photovoltaic system – a system functioning with solar cells, electrical connections, mechanical components, controllers, and mounts to converts light into electricity.
- Monocrystalline – involves solar panels made from a single and large silicon crystal, making them highly efficient.

- Solar energy – power released from the sun in the form of radiation.
- Photovoltaic efficiency – power generated by solar cells to the ratio of radiation reaching the cells from the sun. This rate can vary in the day due to certain factors such as temperature.
- Solar thermal – the process of harnessing solar power for thermal energy.
- Thin-film – a semiconductor material with a light coating like amorphous silicon dropped on a plate of glass directly.
- Watt (W) – the unit of electrical power with respect to time. It is also the amount of work produced in a specified time. An ampere of current moving at the latent of one volt can generate a watt of power.
- Solar constant – the average density of solar radiation calculated at the earth's mean distance from the sun and outside the earth's atmosphere. This rate is equal to 0.140 watts per square centimeter.
- Volt (V) – this is the unit of voltage. If operating on resistance of one ohm, one volt generates an ampere of electrical current.
- Tracking Array – an array of the solar system based on the path of the sun. In this case, it maximizes the solar radiation occurring on the surface of your solar panels.
- Solar spectrum – the process of distributing energy released by the sun organized according to wavelengths.
- Voltage – electrical power that causes the current to move in a circuit as it forces the electrons to circulate.
- Transformer – a device for the transmission of electricity from a circuit to another. It can reduce or increase the voltage during transmission processes.

CHAPTER TWO

What are the Designs of Solar Power Systems?



Solar system

Green energy has become an alternative source of power in many homes and businesses. This is done to reduce over-dependence on fossil fuels. Designing a solar power system is building the unit, choosing the equipment, and estimating the ratings of the tools used in the structures.

A solar panel is about sixteen square feet and differs in size. They are designed in a rectangular shape fitted to racking systems.

Solar power systems are made in different ways following some procedures such as:

1. The Power Usage Statistics

Before purchasing and installing your solar system, consider the power usage statistics. This depends on the sources of electricity available to the home unit. Decide if the house will have solar energy as a supplement to power from the community's power grid.

In most cases, you can decide to go off-grid. That means your building will not depend on power from the typical grid, but the solar installations will supply electric energy to your apartment.

2. Sun Hours on the Building

The amount of power a solar system can produce is determined by the sun's hours. Most buildings don't receive enough sunlight. This will reduce the sun hours, making installing several solar panels difficult.

You can use a tool such as Google Sunroof in determining how many usable sun hours your building is receiving in a year. Another method is using satellite photos of a particular building.

3. Battery Storage

During nighttime hours and cloudy days, it is difficult for the unit to generate enough power to sustain your household. But on sunny days, your solar panels can produce the necessary power for your appliances and other utilities.

Due to this imbalance in power supply, battery storage is necessary, especially if your home, car, RV, or van is connected to the general grid. It is impossible to power your small home using the common grid.

If you want to enjoy a constant power supply, you should back up your home's power supply using a solar battery.

4. Conversion of Direct Current to Alternating Current

Solar panels produce direct current, but an energy converter is used to make the power use. It serves as a transition point for converting DC energy from the battery system in your houses or solar panels to usable 110 volts or 240 volt AC power.

You need a large power converter that can convert enough energy to carry all your home appliances. If you are using a small converter, it may not convert all the required energy to power your devices.

Maintenance of Solar System

Most solar power systems don't need much maintenance, and they are sturdy and can withstand inclement weather conditions. They may be damaged by lightning, hurricanes, tornadoes, and hail. But with insurance coverage on your home, they may be replaced if there are damages.

As a homeowner, here are maintenance tips for your solar system:

a. Always monitor the PV panels and be assured that the inverters are blinking green lights.
b. Keep a record of solar panels' daily performance to note their output on cloudy days and sunny days.
c. Photovoltaic panels may not be affected by rust or breakdown since they don't have parts.
d. Ensure your solar systems are not shaded by trees or other structures that could prevent them from absorbing solar energy.
e. You can use sprinkler systems, which are automated cleaners in cleaning your solar panels if you don't have time to do it manually.
f. Have monitoring systems that can help you to know how much feed-in-tariff to benefit from.
g. Use long handle wipers to clean the panels from the ground surface.
h. Clean the panels when they are wet for a better cleaning experience.
i. Do not use abrasive soap or sponge in cleaning the surfaces to prevent scratching the panels.

j. Always remove dust and dirt from the solar panels to stop them from absorbing sunlight on the surface of the PV panels.
k. If you must climb the roofs, use safety ropes or harnesses to avoid sliding off the roof and falling.

Occupational Safety and Health Administration Silica Exposure Rules

Globally, most solar panels are made of crystalline silicon. This type of panels are popular and the choice of many homeowners. The reason is that a crystalline silicon photovoltaic cell can convert solar energy with twenty-five percent efficiency.

Therefore, OSHA silica exposure rules were established due to exposure to crystalline silica due to the health challenges caused by exposure. This substance is known to cause kidney disease and lung cancer. It can also cause silicosis and COPD.

Workers are exposed to breathable silica substances. They need adequate protection to reduce the risks of these ailments. It is also recommended that workers using respirators for more than thirty days a year should undergo a medical checkups.

CHAPTER THREE

Understanding How Solar Panels Generate Electricity

Proper knowledge of how solar panels generate electricity will help you know how to handle the systems. This will make you embrace the system as an alternative source of energy.

The cells in your solar systems are made of silicon. The element is regarded as a semi-conductor capable of generating electricity in a process known as the photovoltaic effect. These panels function by producing direct current and transforming it to alternating current, which is usable in the home through the inverter.

At this point, alternating current is distributed throughout the home. PV cells absorb energy from the sun and convert it to DC electrical energy.

A solar module comprises a metal frame, a circuit system, a glass casing, and a layer of silicon cells. Silicon is a non-metal but has conductive properties. This feature enables them to absorb and convert sunlight into electricity.

Electrons are set in motion by the interaction of light with silicon cells. This causes electric currents to flow in a process known as the photovoltaic effect. This is the pivot of the functionality and features of a solar power system. Excess electric currents are released to the general power grid.

The Origin of the Photovoltaic Effect

The photovoltaic effect was initially discovered by Edmond Becquerel in 1839. It is the feature of semiconductors to produce electricity if exposed to sunlight. Therefore, the capacity of solar panels to generate electricity is hinged on this electrical effect.

Grid Connection and Solar Panels

Are you still wondering about how the grid factors into the solar system in the home? If your apartment is connected to the general grid, your power supply will provide a utility meter. This is used in measuring the amount of electricity supplied to your home.

If you install solar panels on your apartment, they will be connected to the utility meter. The volume of electricity generated by your solar system will be measured by the metering system too.

You can also acquire net metering. It is a crucial incentive for the solar system that improves the economics of a PV system. Net metering enables you to send energy to the power grid if your solar system generates excess power. This extra power generation happens in the summer months. You can use this to exchange for credits on your electricity or utility bill.

With these generated credits, you can draw current from the grid in low power production days such as cloudy days or night time. Net metering helps you store excess electrical energy with the common grid as credits to be utilized in days of emergency on your private (solar) power system. Therefore, solar is an all-in-one energy solution for every home.

You don't have to worry during bad weather because net metering will give you access to energy from the grid at all times.

Other Necessary Components of Solar Systems

Other necessary parts of a solar system include a glass casing, insulation layer, protective back sheet, and anti-reflective coating.

Glass Casing

The glass casing protects the silicon cells in the solar panel, making them durable.

Insulation Layer

The insulation layer is found under the outer parts of the glass. It is vital in the panel because an increase in temperature will reduce the solar system's performance and efficiency.

Protective Back Sheet

This feature protects the interior parts of the panel against moisture and dissipation of heat.

Anti-Reflective Coating

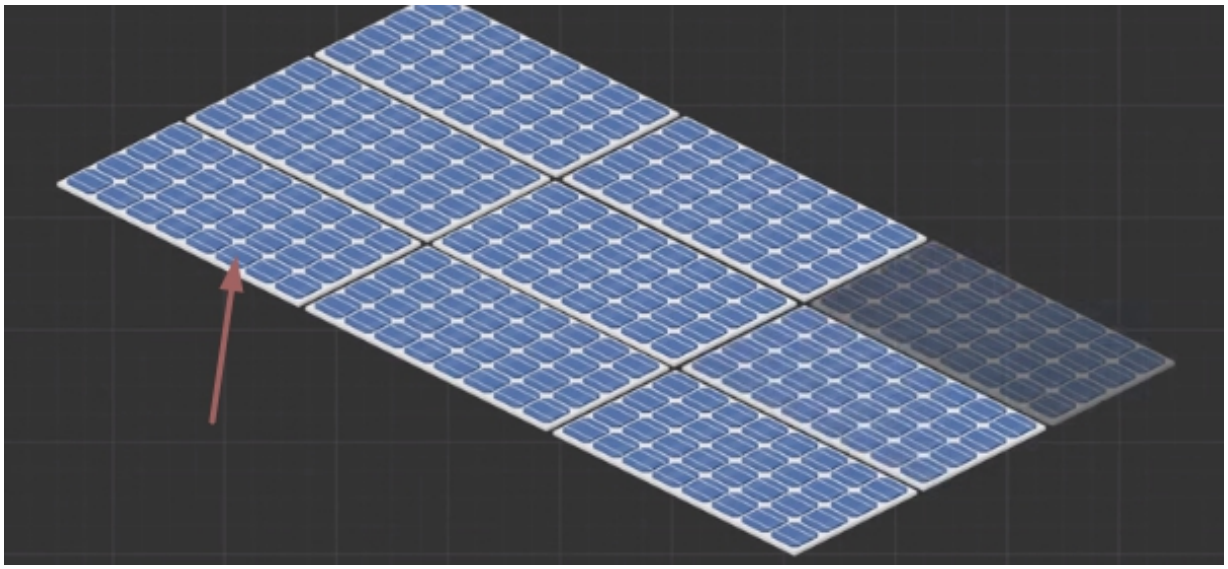
The anti-reflective coating enhances the absorption of light from the sun. It enables these silicon cells to receive greater exposure to sunlight.

Moreover, silicon cells are produced in two formats, such as polycrystalline and monocrystalline. Polycrystalline cells are made with pieces of silicon.

Also, monocrystalline cells are made of a single silicon crystal. Electrons can quickly move around in a monocrystalline format, thereby producing higher efficiency. But the price tag for mono-formats is higher than poly-formats.

CHAPTER FOUR

The Sizes of Solar Panels



Sizing Solar panels

Seeing solar panels on rooftops is a common sight nowadays. But figuring out the actual size of these panels is difficult. The average size of these photovoltaic panels is 5.4 feet in length and 3.25 feet in width. This is about 65 inches by 39 inches. But larger apartments can carry solar panels measuring about 6 feet in length.

Each solar panel comes with separate PV cells measuring about 156 millimeters by 156 millimeters. In approximation, the size is 6 inches in length and 6 inches in width. Rooftop solar panels contain 60 solar cells. But the standard for industrial installations is 72 cells and could increase to 98 cells or even higher.

Differences between Residential and Commercial Solar Panels

a. Residential solar panels contain sixty solar cells, while commercial solar panels consist of seventy-two solar cells.

b. The average length of residential panels is sixty-five inches, while commercial panels are seventy-eight inches.
c. The average depth for residential panels is 15-2 inches, while commercial solar panels have 15-2 inches.
d. The average width of residential panels is thirty-nine inches while commercial solar panels measure thirty-nine inches.

However, the number of cells in a panel is directly proportional to its length. If you compare commercial panels with seventy-two solar cells, they are thirteen inches longer than the residential ones with sixty solar cells.

Weighing Rooftop Solar Panels

It is essential to know the weight of solar panels to ensure that your roof can carry them. You can determine the weight by checking the product specifications of the panels before buying.

Depending on the brand and type of solar panel you are going for, an average residential solar panel weighs about 40 pounds. Some brands also weigh about 33 pounds, while others like Canadian Solar weigh about 50 pounds.

Therefore, if you need two solar panels weighing about 40 pounds on your roof, ensure that the top can support up to 80 pounds of weight. Also, if you need five solar panels, meaning that 40 pounds x 5 = 200 pounds of weight on your roof, etc.

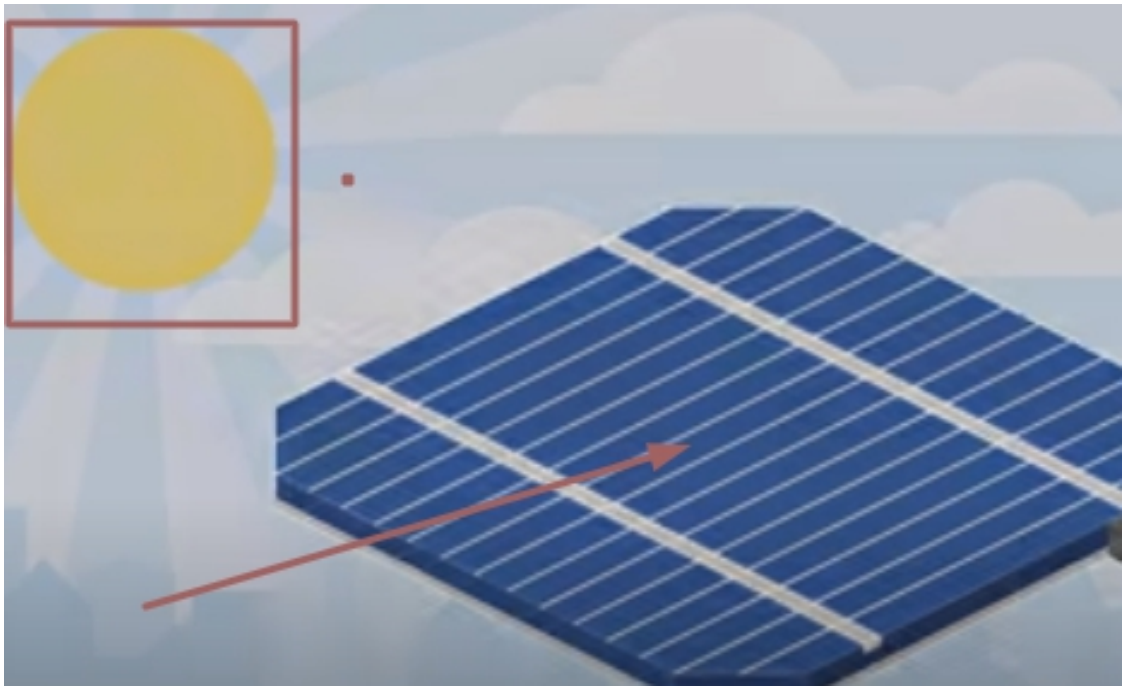
How to Measure the Size of Roofs for Solar Panels

To measure the size of roofs for solar panels, determine how many solar panels you need in your home. This depends on the amount of electricity your household consumes. It also depends on the usable surface area of your roof.

Other factors include the peak sunlight in your locality. Weather conditions can also determine the size of roofs for solar panels. Consider the wattage, net metering, and relative efficiency of the PV panels you want to use.

But the best way to know the size of the roof to use for mounting your solar panels is to consult a solar installation expert.

The Equator and Solar Systems



The Inclination of the Sun and Solar systems

Solar power released on the earth's surface is affected by two factors such as the thickness of the atmosphere between the sun and a given area; and the inclination of the rays of sunlight over a given geographical axis.

In the midday, the sun can be at an angle of ninety, over human heads. But at sunset, it will be at an angle of 0. However, it is never at an angle of ninety in most places but at a maximum angle where it radiates the highest energy. The degree of radiance depends on the thickness of the atmosphere over such a place.

If the atmosphere below the sun is very thick, it will filter the radiation of sunlight. Then, as the sun goes from a higher point to a lower end, the energy continues to reduce until the sun is covered on the horizon.

Using the inclination of the rays of sunlight over a particular, you will observe that the earth's axis of rotation is not perpendicular to the translation plane of the earth around the sun. This will give us an inclination angle of 23.5.

Now, the tropics include two lines that are parallel. One is at the north, while the other is at the southern part of the equator. When the sun gets to these lines, it is at ninety degrees over the surface of the earth. At this point, it has got to its highest angle in the solstices, which is usually June 21st . On this date every year, the sun gets to its highest point in the northern hemisphere. It also gets to its lowest point in the southern hemisphere. This angle is directly perpendicular to the Tropic of Capricorn.

Therefore, globally and all year long, the sun smites at angle ninety at the equator. Solar panels will receive the highest solar energy at this point. This degree of power does not occur in the northern hemisphere because the sun's angle reduces as you move from the equator to the north.

At the same inclination, the parallel geographical point gets reduced rays of sunlight, including solar energy. However, as you proceed northward, the thickness of the atmosphere between the sun and earth's surface grows bigger and thicker, making it difficult for the rays of sunlight to effectively hit your solar panels.

How Solar Cells Work

Solar cells are combinations of N-type silicon with blue color and P-type silicon with red paint. The solar cells produce electricity using light from the sun in making electrons.

As sunlight shines on the solar panels, light particles, otherwise called photons, hit the upper surface. The photons are represented as yellowish blobs that transfer their energy downwards the cell.

However, the photons surrender their energy to electrons in the P-type layer. The electrons cross over hurdles to the upper N-type layer and enter the circuit. These electrons cause the lamp to light up as they flow around.

What is the General Formula for Panel Sizing?

The way to know the size of solar panels you need is with your previous utility bills. The general formula for panel sizing is multiplying your household's hourly power consumption by the **peak hours of sunlight** in your area. Then, divide the figure you have by the wattage of the panel.

CHAPTER FIVE

The Orientations of Solar Panels

The orientation of your solar panels matters as much as the type of solar panels you installed in your apartment. If the rays of sunlight hit the surface of your panel in a perpendicular position, the panel will absorb more power for your home's use.

Placing your solar panels in the proper direction where they will have more tilt is necessary. This will cause them to be positioned towards the sun's area of intensity. Most persons use the solar tracking system to enhance the panels' energy production when exposed to the sun's rays.

Solar orientation follows two methods, which are

a. **Tilt or Angle** – this feature is necessary for solar power systems. Geographical latitude determines the angle a solar system should be set to generate more energy within a year. Setting the tilting angle of your solar panel to the geographical latitude is a common rule for optimizing your annual energy production. This means that if the solar array is located fifty degrees latitude, the optimal tilt angle is also fifty degrees.

If your solar panel is placed closer to the equator, the panel will be tilted upwards. As the panels are slanting towards the poles, they should be tilted more towards the equator.
Climatic and environmental factors could, coupled with the angle of your solar panels, could affect energy output. Slanting your solar panels wintry seasons, accumulation of snow on the panels could hinder the rays of sunlight from hitting the panels leading to low or no power generation. But this effect varies from region to region.

b. **Direction** – A standard rule for placing solar panels in the northern hemisphere is that solar panels should face true south. But if in the southern hemisphere, the panels should face true north. This is the best direction since solar panels will get enough sunlight during the day.

But true south and magnetic south are two different phenomena. The south that is displayed when a compass is used is known as the magnetic south. It faces the earth's south magnetic pole. Solar panels are designed to face solar south or geographic south. This is the direction towards the South Pole. Due to this analogy, if the panel is situated in the southern hemisphere, it should face true north. Depending on your choice, you can slightly slant or rotate your panel away from the true south, which could be very beneficial.

You can tilt your panel to face south-west depending on what you are using the panel to do in some cases. These panels collect more energy, which is more useful during the day if they face due south. The rotation causes the panels to generate more electricity whenever they are needed.
On this note, rotating the solar panel towards sunset is south-west will make your home receive enough light in the evenings to power your appliances. But most homes are provided with electricity from other sources in the morning and midday.

Placing your Panels on a Flat Roof

The type of solar panel installation you choose for your home depends on the structure of your roof. You can use a solar tracking system to update your solar panels. Installing panels on flat roofs need some set of tools to optimize the electricity output.

Installers can move around quickly on flat roofs without special equipment. They are not required to make holes on the roof before installing the panels. A ballast system, which is a weighted mounting system, is used for flat roof installations. It applies the force of gravity to remain on the roof without boring holes.

But solar panel installation on slanting rooftops requires a penetration mount used for attaching the racking holding the solar panel.

To place your solar panels on a flat rooftop, you need to orient them to face south. But they should be mounted at the correct angle, notwithstanding the direction your home faces. With these, you can easily optimize your panels for efficient power generation. This entails better performing solar installation for your apartment.

Placing your Panels on a Pitched Roof

Among the solar mounting categories, pitched roof placement is a sub-type of these mounting systems. We also have solar shingles and a sloped-roof mounting system.

But pitched roof mounting system involves installing to the pitched roof frameless and framed solar panel modules. It is ideal for commercial buildings and residential buildings.

There are different sub-types of pitched roof installation systems such as corrugated, raised panel, tile, standing seam, and in-roof.

Basic features of Pitched Roof Mounting System

a. Pre-assembled parts with customized solutions making installation easy, fast, and popular.
b. Easy to install with interchangeable parts and minimal components.
c. Installation should be done on the part of the roof with maximum exposure to sunlight.
d. The roof of such a building should have a pitch of thirty degrees, facing the south, sunny, and spacious.
e. Designed with light-weight, strong, durable, and corrosion-resistant aluminum
f. This type of mounting system could be affected by the shape of the roof, different kinds of pitches, and roofing structures.
g. You can fit modes in landscape or portrait.

Pitched Roof Mounting Components

The mounting components of a pitched roof system include an **inter-clamp kit, rail, rail splice kit, braided earthing strap, grounding washer, end clamp kit, and grounding lug** .

Various Types of Pitched Roof Mounting System

1. SolidRail System

Different load profiles come with various mounting rails. The system is strong and durable, with greater flexibility for ranges of widths.
The components of roof fastening in this system include

- Solar fasteners – ideal for corrugated fiber cement roofing or corrugated sheet metal.
- Roof hook for slate roofing – has three boreholes for a secure fit.
- Roof hook for plain tile roofing – suitable for double roofing too.
- Vario 1 and 2 roof hooks – for pantiles. You can adjust the height at battens and under the bracket.
- Roof hook for pantiles - designed in various sizes with durable stainless steel.
- Hanger bolts – for sheet roofing with wood as a substructure. Used for corrugated sheet metal with customizable height adjustment.
- Roof hook for Coppo roofing is adjustable under the bracket with a flexible position on the rafters.

2. SpeedRail System

This is a long rail system for using a floating suspension with regulated thermal linear expansion, including the trapezoidal sheet. It is ideal for high-loading and easy to install.
The roofing components include:

- SpeedLock – this lock is necessary for SpeedRail and useful for thermal expansion. It is designed with a stainless steel and slot nut.
- SpeedRail – for inserting SpeedClips into mounting rails and available in different lengths.
- SpeedConnector – Used as a rail connector for SpeedRail with three boreholes for quick mounting. It includes a set of countersunk screws.
- SpeedClip – Comes with mounting brackets for SpeedRail. The trapezoidal sheet metal could be fastened with self-drilling screws.

3. SingleRail System

This is a fast and low-cost system for direct lateral connections to the rail. You can easily adjust the height of the structure if you need it. No need to screw the system into the base plate since it has a secure snap-in assembly. It is a versatile and durable system if used together with CrossHook roof hooks.
The Components for Roof Fastening in this system include

- SingleHook – for pantiles and suitable for narrow rafters. It is easy to adjust.
- CrossBoard – suitable for nogging and skylights.
- CrossHook 4S – for pantiles with three heights adjustment in the base plate. It is made for narrow rafters.
- SingleHook FT – for flat tiles and pantiles. It is independent of rafters and used on small rafters.
- CrossHook 3S – for pantiles with three height adjustments in the base plate and suitable for rafters.

- Hanger Bolts SR – suitable for corrugated fiber-cement roofing with wooden substructures.
- Standing Seam Clamps – for different types of the seam.
- SingleHook Vario – for flat tiles and pantiles with adjustable height at battens and rail connections.

4. MultiRail System

It is simple to mount and features a short rail component with different lengths.
The necessary components for fastening on the roof include

- MultiRail 4200 mm – the long rail is used for making customized sizes. You can fasten the component using adhesive with a length of 4200 mm.
- MultiRail 250 mm – for high loads with horizontal module orientation using greater flexibility.
- MultiRail 100 mm – the orientation of this module is horizontal with a length of 100 mm.

5. S-Dome Small System

This system is useful for roofs with an inclined angle of fifteen degrees. It has a strong holding power and affordable.
Components of this roof fastener include

- Dome SD Small – this is a support element for a narrow module.
- FlexClamp Small – It has an adjustable height with clamping on the long side of a solar module.
- MultiRail 250 mm – It has a length of 250 mm with an inclination angle of fifteen degrees and four boreholes for mounting.
- Dome S 1000 Small – used as a support factor for a solar module with narrow elevation.

6. Insertion System

Insertion system is easy to assemble with no tools and quick to install with no clamps. It comes with a continuous, closed surface. The components of this system include:

- Hanger bolts – it is useful for cement roofing or corrugated sheet roofing. Hanger bolts have a wooden substructure with an adjustable height.
- Insertion rails – offers a solution for installing a highly effective solar module.
- Cross connector – Easy to mount and useful for the insertion of rail on SolidRail.
- Cable management – .you can handle up to five cables with this system. It features a fast cable connection under the insertion rail.
- Accessories – these accessories include a side stopper, connector insertion rail, and a horizontal end bracket.
- CrossHook 3S+/4S+ - easy to adjust the height and suitable for narrow rafters.
- SolidRail – a robust mounting rail used for large spans with several load conditions.

7. MiniRail System

It features a smaller and inventive mounting system that can be mounted easily. This system is a suitable portrait orientation or ideal landscape with five degrees inclination, optimal module angle, and improved ventilation.

- MiniRail – for landscape and portrait mounting using MiniClamp.
- Self-tapping Screws – designed with sealing washers and added in MiniRail.
- MiniFive front and End – for greater output and improved ventilation with an optimized module angle, including a single-sided easy elevation.
- MiniClamp 30-50 mm – a rotatable universal module clamp.

Inter-row Spacing of Solar Panels

Now, you should learn and understand how to estimate inter-row spacing for ground-mounted PV systems and tilted solar panels. You can increase the size of the array and prevent shading on the devices.

Naturally, determining the actual spacing between the rows of solar panels could be difficult. You need to take caution to ensure rows of panels do not cause shading on each other, especially those behind them. This situation can cause the system to perform less than expected.

Follow these steps to calculate the inter-row spacing of solar panels:

- Determine the height difference from behind the module to the surface. You can use this formula:

Height Difference is equal to Sin (Tilt Angle) x Module Width
Do not calculate in radians but degrees.
If I decide to use a module designed by SolarWorld, for instance, with a width of 39.41 inches at a tilt angle of 15 degrees.
The height difference becomes Sin (15) x 39.41
Height difference is equal to 10.2 inches. This could be rounded down to 10 inches.

You can determine the elevation angle of the sun by visiting this site. Then, enter the zip code of your location. Also, you can enter the longitude and latitude of your area for a precise result. The Azimuth angle can also help you calculate the panels' inter-row spacing on your solar array.

CHAPTER SIX

How to Choose Solar Panels

Choosing a new solar panel involves some techniques since it is a long term investment. You need to pick a good brand at an affordable cost carefully.

Calculate the Cost

The first thing to calculate here is the cost of a solar panel. Different factors culminate to determine the price of a solar panel. These include

a. The size of the panels you want to buy.
b. The brand of solar panels.
c. Durability
d. Warranty or certifications.
e. The size in watts.

However, panels' cost might not be the only deciding factor because costly ones may not be too efficient.

Consider the quality based on how it is produced, including the quality of materials used in production. Different producers manufacture solar panels that are different in price, quality, and effectiveness. These manufacturers invest much time and resources into research and development to ensure that their products perform optimally.

Some producers only assemble panels but don't invest in research. Therefore, check to see if there are satisfied clients before committing your money.

Another feature to consider is the size. That means the physical size and size of the wattage. The size of the panel should be big enough to carry all your electrical appliances. Also, ensure that your space is enough for proper installation processes.

You need a 4 kilowatt the solar system to power an average household. In this case, a panel producing 100 watts will have 100-watt hours, while a 4-kilowatt panel will give you about 4,000-watt hours.

In general, solar panels could cost about $19,000 if you use a 6kW solar panel made for industrial centers. Also, residential areas with 3kW or 8kW can cost from $9,300 to $25,000, including the installation cost.

Check the Warranty Options

Accessing the warranty options is a sign that the product will be durable. A manufacturer expresses confidence in his products through warranty offers. Solar panels are designed to have about twenty-five years of warranty. If the product has a shorter warranty period, it is a sign of inferiority, and you may not trust such panels.

Proper maintenance of the solar systems will increase their lifespan and longevity.

Assess the Technological Efficiency

The technical efficiency is based on the amount of light the panel receives, converted to electrical energy. This also entails the degree of power your solar system can generate. If the system is more effective, it is a better option, and therefore, more expensive.

A good recommendation is to get a bigger and more efficient panel to meet up your energy needs.

CHAPTER SEVEN

How to Maintain Solar Panels

Here are some maintenance tips for solar panels:

a. Ensure your solar panels are not covered by shadows that can reduce energy production.
b. You can know the amount of carbon dioxide you are releasing into the environment and how much feed-in-tariff you should receive using monitoring systems.
c. Always check your solar systems and ensure that the inverters are blinking green lights if you do not see the green lights beaming, no compensation for using your electricity.
d. Solar panels may not suffer mechanical breakdown and rust and may require little or no maintenance in that area.
e. Install automatic cleaners for cleaning the system if you can't do it manually. This works like a sprinkling machine.
f. Schedule cleaning appointments with solar panel cleaning firms for routine maintenance.
g. Information about your solar panel servicing could be showing on a wall-mounted display.

If you decide to clean your solar panel, here are some tips that can help you get it done quickly and easily.

1. Solar panel cleaning kit comes with a wiper, a brush with a handle or a smaller brush, and a biodegradable soap. Pour the soap into a bucket with water. Put the brush inside the soapy solution and begin to wipe the panels gently. Stubborn stains or grime could be handled by wiping the surface with a soft brush and clean water to avoid scraping the surface. Also, following

the instructions on the bottle will guide you to clean your system correctly.

2. Never use hard or harsh materials in cleaning your panels to avoid damage to the unit.
3. Avoid a build-up of dirt and dust by cleaning the system regularly.
4. If you must climb the roof, use harness or safety ropes for support.

5. Try to clean your panels when they are wet.

How to Choose an Inverter

Buying inverters require a careful plan to get a good one to carry your appliances in the home or business. Here are some things to consider before buying:

a. Understand the amount of electrical energy that can power your appliances.
b. Consider the Volt Ampere rating of the inverter you need. This is regarded as the voltage and current supplied by your inverter to the home appliances.
c. Select a good battery for your inverter. The battery is the life, power, and performance of an inverter system. It determines the backup power of an inverter system and the number of hours it can carry your home. This is also known as the battery capacity and expressed in Ampere Hours (Ah).

Inverters on the market have various capacities such as 100 Ah, 150 Ah, etc. You can calculate the battery capacity of your inverter using the power efficiency of your inverter. If an inverter is functioning at 100% efficiency, it means the power supply from the inverter and your appliances' power needs are the same. But usually, inverters have efficiency ranges from sixty percent to eighty percent.

The efficiency of inverters is also known as the **Power Factor.** It is the **ratio of power needed by the appliances to the power supplied by the inverter** . This power factor ranges from 0.6 to 0.8.

Now, if you need a battery that can give you three hours of back up. It should be:

Energy requirements at home x Backup hours / Voltage of Battery = Battery capacity.

Therefore, Power is calculated in watts, Backup hours are estimated in hours, while Battery voltage is in volts.

Disadvantages of Inverters

Do you think your inverter system could have disadvantages? First of all, here is a brief analysis of the advantages before we understand the drawbacks.

Advantages

- Cools and heats up efficiently.
- Runs on solar panels.
- The use of better refrigerants makes it a right choice for green energy.
- Ideal for small or large apartments.
- Provides lower power consumption useful for house circuit system.
- Ensures consistent room temperature.
- The compressor makes power fluctuation difficult.
- An inverter consumes less power compared to a usual AC, making it about forty percent cheaper to manage.

Disadvantages

But the disadvantages of using inverters include

- The inverter's efficiency reduces at noon when the weather is sweltering above forty-five degrees Celsius.
- If the model is underpowered, it may run more often at maximum output, causing the air to dry up too much.

- Energy consumption increases if the room is not insulated, causing the electricity bill to grow too.
- Achieving the target temperature makes models that are too powerful for the room's size to run intermittent short cycles. This will help them to achieve the target temperature result.
- This condition could make the room become too hot or too cold. Also, poor dehumidification could make your apartment uncomfortable, leading to increased energy consumption, wear and tear, and more running costs.

Phases in a Solar System

A solar system can have up to three phases, and you can connect them easily. You can also connect your solar system to the grid in three ways:

a. Using a single-phase solar inverter in connecting your solar system to one of the supply phases.
b. Using a three-phase solar inverter in connecting your system into all three phases of your supply.
c. Using three separate single-phase inverters in connecting your system into all three phases of your supply.

If you are contemplating the plan to set up for your apartment, you should also understand how to benefit from feed-in-tariffs.

You should know how to balance loads on the three phases to maintain the demand across the phases. This is necessary to boost the power quality. If voltage is problematic on any phase, it can cause inverters always to trip out.

What are Hidden Losses in a Solar System?

In a photovoltaic array, some hidden losses are occurring in the system. These losses are reducing the global yield. The PVQAT – International PV Quality Assurance Task Force was established to embark on research to identify faults in solar panels and address the issues to minimize power losses.

These problems could be a result of geographical or climatic conditions such as desertification, temperate conditions, and tropical regions. Other issues that could cause a loss of power are mistakes during installation.

Another problem is a defect as a result of the degradation mechanism. This fault is not based on manufacturing processes. This degradation process causes the system to reduce its original or nominal production capacity.

You also have the problem of mismatch and shading faults. This defect occurs due to permanent sources and temporary sources. Examples of permanent origins of mismatch defects include cracking of modules, degraded performance, and manufacturing tolerance.

Examples of temporary sources of defect occur due to differences in radiance arising on the panels' surface. These mismatch losses lead to a reduction of the power generated during the peak hours of the day.

CHAPTER EIGHT

Solar System Buying Guide

If you have decided to purchase a solar system for your household, here are some buying tips that can guide you accordingly:

1. Consider the duration of the producer's warranty – understand the type of guarantee offered by the manufacturer, especially consider the duration. Reputable manufacturers usually offer twenty-five years warranty. Therefore, you should expect your PV panel to last for a longer time.
2. Access the type of panels available before buying – Due to limited spaces on roofs, you may consider monocrystalline photovoltaic panels that are efficient but expensive. You may also decide to purchase thin-film panels or the more advanced polycrystalline panels. If your roof has enough space, consider the panel's size and energy output you want to buy. Don't clutter your roof space with inefficient solar panels.
3. Before mounting the solar panels – ensure that a certified engineer checks and approves the area you want to mount your solar panels, even if it is on the roof or ground. This is to enhance efficiency and prevent shades from affecting the panels. The solar system should be cyclone-rated and wind-rated. This is to control your PV panels from being removed by a wild storm. Ask relevant questions from the dealers before purchasing.
4. Ask for quotes from different providers – getting quotes from various solar systems providers will give you other price lists for a range of products to choose from.

5. Get recommendations from friends, colleagues, neighbors, and family – ask your friends, colleagues, or neighbors who had already installed solar panels, and they will give you tips on the best brand to buy. You will learn from their experiences and avoid issues that affected them.
6. Do not succumb to high pressure from salespersons – do not make buying decisions on your solar panels on the spot. Ask the salesperson to give you some time. High-pressure sales method has led many into the pitfall of buying the wrong solar panels.
7. Consider the solar panel's efficiency – the system that converts direct current (DC) electricity from your PV panels to alternating current (AC) is the inverter. It is the box between the appliances and the panels. Most solar inverters are not equal and not efficient.

Efficient inverters easily convert direct current to alternating current without wasting much heat. Evaluate the efficiency of these inverters before purchasing and beware of generic brands.

8. Get solar panel certifications for possible rebates from the government – this is necessary for purchases of solar panels. Each certification indicates the type of testing they have undergone. Suppose you see a solar panel with this certification – TUV IEC 61215. it means that the product has undergone tests by a separate laboratory and trusted professionals and met the standard requirements or specifications.
9. Look for solar panels with real prices – don't go for products with too low prices. This may mean poor installation or low quality. If you notice that you are paying an amount less than other products of the same category or specification, endeavor to ask questions. This will prevent you from buying an inferior panel that you may regret later.

How to Buy Online

Locate online retailers of solar panels and accessories, including energy efficiency products, and contact them to select and purchase. They will guide you in making a right buying decision. Various solar panels come with different watts, such as

a. 1 - 90 watts – small panels for charging RV batteries and other smaller off-grid equipment.
b. 91 – 159 watts – for charging RVs, including class-one Division 2 environments.
c. 160-199 watts – for off-grid systems according to the size of panels.
d. 200 – 299 watts – PV panels used in older solar arrays.
e. 300 Watts and above – for strong PV panels.
f. Thin-film solar panels – lightweight, durable, and flexible.
g. Pallets of Solar panels – you may get special discounts for ordering full pallets of solar panels.

How to Buy Offline

If you don't want to buy online, you can locate a solar panel and accessories store near you to choose from. You may get a 12-volt system, 24-volt system, and 48-volt system for your off-grid solar system.

Before releasing your bucks, ensure that you check through the product manual for the necessary information to guide you in making a decision.

Here are some things to consider:

a. Solar panels: for absorbing the rays of sunlight and converting it into electricity. Examine the voltage, string size, and amperage. Ensure the panels are compatible with power centers, batteries, and other accessories on the package. Finally, understand the warranty offers and ensure that the system can run uninterruptedly for 24 hours a day. Some examples of solar panels include Astronergy 320, Heliene 320,

b. Racking system for ground mount or roof mount.
c. Power Center: this is a pre-wired inverter used in off-grid settings. This center involves an inverter, circuit breakers, charge controller, and remote control.
d. Add-ons for power centers: these include Kohler 12kW off-grid generator package, Kohler 28kW off-grid generator package, Schneider Conext ComBox, and Schneider Conext Auto Generator Start (AGS).
e. Battery or Power bank: stores energy generated from the panes. Examples include lithium batteries, flooded lead-acid, and sealed lead acid (AGM or Gel) such as Crown CR430 flooded lead-acid battery, Fullriver DC400-6 AGM Sealed Lead Acid battery, and Discover AES Lithium battery.

CHAPTER NINE

How to Read Solar Panels Technical Data Sheets

A solar panel's technical data sheet comes with various terms and ratings that a beginner may find confusing and difficult to understand. Some of these specifications include

a. **Normal Operating Cell Temperature (NOCT)** – solar panels on your roof in the summer can heat up well above 100 degrees Fahrenheit. NOCT helps you to get a realistic view of natural world scenarios. Instead of giving you one thousand watts per square meter, you can get eight hundred watts per square meter. This energy rating occurs when there are scattered clouds over a sunny day.

In this condition, solar panels use an air temperature of twenty degrees Celsius, not a solar cell temperature. It also involves a 2.24MPH wind cooling the back of a ground-mounted solar panel seen in larger solar arrays. NOCT rate is more realistic but lower than STC.

b. **Short Circuit Current (Isc) -** this is the amount of current or amps the solar panel generates when the plus or minus of the wires are directly connected, especially if it is not connected to a load. You can read the short circuit current by measuring the system with an ammeter. This Isc is the most significant current your photovoltaic panels will generate under standard test conditions. You can determine how many amps a connected device such as inverters, charge controllers, etc., is used by the short circuit current and multiplied by 1.25 for NEC (National Electric Code eighty percent requirements.

c. **Standard Test Conditions (STC)** – every solar panel is tested using the same standard test conditions. Depending on the

intensity of light and temperature, voltage and current can change. These changes are observable on the solar cell's temperature of 25 degrees Celsius, the atmospheric density of 1.5, including the sun's angle, which could be directly perpendicular to the solar panel at 500 feet above sea level. Also, you can see it in the light intensity of 1000 watts per square meter.

d. **Open Circuit Voltage (VoC)** – the number of volts the solar panel releases without any load. You can read open-circuit voltage by placing the voltmeter across the minus plus leads. This result is essential since the maximum voltage the solar panel can generate in normal test conditions. This rate is valuable when you want to know the number of solar panels to wire in series into the charge controller and inverter.

e. **Nominal voltage –** this is a category of voltage. It is not a real and measurable voltage. It enables you to know which equipment can go together with others. For instance, a nominal solar panel of 12 volts comes with an open-circuit voltage of 22 volts and a maximum power point voltage of 17 volts. This panel can charge a 12-volt battery.

f. **Maximum power point current (Impp) –** In normal test conditions, it is the actual amperage you can see if the solar panel is connected to the MPPT solar equipment such as charge controllers, etc. It is the current or amperage you observe when the output power is at the highest point.

g. **Maximum power point voltage (Vmpp) –** this voltage occurs when the power output is at the highest point. You can see the real voltage if the panel is connected to the MPPT solar devices such as inverters and charge controllers.

h. **Maximum power point (Pmax) –** a combination of the volts and amps on a solar panel power output leading to the highest wattage. That means Volts x Amps is equal to Watts. The MPPT electronics try to maintain the volts and amps to enhance power output. In this case, a solar panel is listed as the Pmax. Then, Pmax is equal to Vmpp x Impp.

Explaining Connection Efficiency

Connection efficiency is an estimation of the solar panel's capacity to transform sunlight into useful electricity. Suppose two solar panels with different efficiency ratings are exposed to the same amount of sunlight for the same duration. In that case, the panel with greater efficiency will generate more power than the other.

The efficiency of solar panels is influenced by the generation of electricity by solar cells. The composition of these cells, their electrical configuration, and surrounding components also affect solar panels' efficiency.

Most PV panels have between fifteen percent to twenty percent efficiency. Some high-quality panels exceed twenty-two percent.

Factors that determine solar panel efficiency

The ability of solar panels to convert sunlight into electricity determines their efficiency. The factors that determine solar panel efficiency include:

a. Reflection: The reflection of lights away from the solar panels can reduce its efficiency. Therefore, the layer of glass on silicon PV panels is essential.
b. The type of material used for making the panel such as cadmium telluride, monocrystalline silicon, and polycrystalline silicon.
c. Wiring and busing: this entails arranging wires and busbars on a solar panel to capture and transmit electricity. This structure of circuits can impact the efficiency of the panels.

How to Read Inverter Data Sheets

Inverter datasheets display the specifications of inverters. Reading and interpreting the specs will determine if you can purchase it for your solar

system or not. Anyone that handles solar panel installation needs to read the inverter datasheets.

The main features of inverter data sheets

Inverter data sheets have some specifications you need to understand before you can install and use it, such as:

1. **Maximum input current –** the maximum direct current generated by the system. If the system's electric current is over this limit, all excess current will not be utilized.
2. **Maximum output current –** the maximum alternating current the inverter can generate at a time. You need to understand this feature and choose protection devices such as circuit breakers and fuses to manage over-current situations.
3. **Protection degree –** this is shown by IP, including its protection level against solid objects' entrance into the system, which is the first digit, and the second digit is waterproof protection.
4. **Maximum power tracking voltage -** is the direct current input voltage range in which the inverter will work in MPPT regions. The system designer should understand this feature properly. Therefore, the string voltage will be designed so that some part of the year, the input voltage of the direct current can fall within that category.
5. **Starting voltage –** this is the minimum direct current voltage needed to start the inverter for grid-tie solar systems.
6. **Compliance certificate** – this certification displays the tests and standards in which the inverter complies with UL, CE, etc.
7. **Maximum efficiency –** this is the highest efficiency derivable from the inverter system. It varies between ninety-four percent to ninety-eight percent.
8. **Rated output power –** the highest intensity you can get from the inverter. It is measured in Kilowatt or Watt.
9. **Rated output voltage is the utility alternating current voltage, which the inverter will be connected to according**

to the electricity distribution system . It could be one- phase or three-phase.

Understanding MPPT

MPPT stands for Maximum Power Point Tracking. An algorithm is added to charge controllers for obtaining maximum energy available from the photovoltaic modules in some conditions. The voltage at which your solar module can produce maximum energy is called Peak power voltage or full powerpoint.

This varies with solar cell temperature, ambient temperature, and solar radiation. A typical solar module can generate a current with a maximum power voltage of about 17 volts if measured at a cell temperature of 25 degrees Celsius. On cold days, it can rise to 18 volts, while on hot days, it can reduce to 15 volts.

Analyzing MPPT Range

MPPT range involves obtaining maximum power available from the solar modules by causing them to function at the most efficient voltage. This is also known as the maximum powerpoint.

Therefore, Maximum Power Point Tracking examines the output of the solar module and compares it to the battery voltage. It harmonizes the best power the solar module can generate to charge the battery. Also, it converts it to the best voltage to get the highest voltage into the battery. It supplies current to a direct current load if it is connected directly to the battery.

From experience, it has been deduced that MPPT is most effective in conditions such as:

1. If the battery is well-charged, MPPT can obtain more current and recharge the battery when the charged power discharges.
2. Hazy days, cold conditions, and cloudy weather. Solar modules function better in cold weather conditions. MPPT obtains available extra power from the modules.

MPPT Solar Charge Controller

You can maximize the electric current amount going into the battery from the solar module using the embedded MPPT algorithm. It is the charge controller with the direct current to direct current converter functioning by taking DC input from the solar module and transforming it into an alternating current. It also transforms it back to another DC voltage and electric current to fit the battery's solar module.

Features of MPPT Solar Charge Controller

a. It is valuable for any solar power system needed to obtain maximum power from solar modules.
b. It causes solar modules to function at a voltage close to maximum power.
c. MPPT solar controller reduces the complexity of the system while the output of a system is high efficiency.
d. It applies to other renewable sources of energy such as wind-power turbines, water turbines, etc.

CHAPTER TEN

Solar System Connectivity

Do you want to increase your solar system capacity? Then, consider connecting solar panels easily and efficiently. Solar system connectivity connects extra solar panels to increase the voltage and energy output of what the system can generate already.

Firstly, decide on the connection method that can give you the desired result. This entails wiring your different solar panels in a **parallel connection or series connection.** With this, you can make larger solar arrays

What is Series Connection?

Series connection involves the process of increasing the total system voltage by connecting solar panels in series. This is possible if you have a grid-connected charge controller or inverter that needs 24 volts or more.

Series wiring is done by connecting the positive terminal to each panel's negative terminal to give you the total output voltage of the array. Do this for each panel until you have only a positive and negative connection left out.

In Series wiring, you can have an array of panels like:

1. Series of solar panels in different voltages – incorporates different types of solar panels with different power ratings.
2. Series of solar panels with different currents – involves different types of solar panels with a different ratings. The separate panels' voltages will add up with the amperage limited to the value of the lowest panel in the series.

3. Series of solar panels with the same features – involves the same type of solar panels with the same power rating. The total voltage output is the sum of the voltage output of each panel.

What is Parallel Connection?

You can use parallel wiring to connect different solar panels. This is the reverse pattern of the series connection. It is used to increase the current of the total system. In this type of connectivity, you connect all the positive ends together, and all the negative ends. That means positive terminal to positive terminal and negative terminal to the negative terminal.

After all these connections, you will be left with only a positive terminal and a negative terminal attached to the batteries and regulators. In a parallel connection, the voltage output remains the same, just like a single panel. However, the output current is the sum of the production of each panel.

In parallel wiring, you can have an array of panels such as:

1. Solar panels of the same features in parallel wiring involve the same type of solar panels with similar power ratings.
2. Solar panels with different currents and voltages in parallel wiring – in this system, the parallel solar panels add up with the voltage adjusting to the lowest value. But the panels must have the same output voltage to be utilized in parallel connection. Any panel with a higher voltage must shed it to that of the lower one to align with the system.

Short Circuit System and Fire Hazard

Anyone considering installing a solar system, should know that photovoltaic plants generate electricity, which is a potential source of fire hazard if electrical faults occur in the circuit system. This is due to the presence of direct current and the layout of the system, including the grounding of the negative pole of the DC.

You should devise means of protection, which are necessary for designing a system that takes care of fire risk. The main focus of this study is grid-tied

solar systems connected to an independent grid system. It feeds power directly into a commercial or residential apartment and returns excess into the grid.

The Main Components of AC and DC Electric Systems

AC and DC electric systems' main components include solar generators, which are panels connected in parallel or series to form multiple arrays or single arrays. You also have an inverter, low or high-frequency transformer, storage facilities like batteries,

Other components include an interface system to the grid, grounding system, surge protectors, and other devices for protection against over-current.

If you design your solar system according to technical standards, you may not overload it. Therefore, no protection device is needed. The photovoltaic system cables can be affected by current coming from a short circuit, especially if there is a fault in the systems with a grounded point and separate systems with a double grounded point.

The differentiating factor between an average plant powered by the network and a solar system is that a PV system is a generator. Therefore, you can install a protective device in the junction box if the cable is too small for the panels' current. With this, you can protect the device from short circuit currents using fuses and circuit breakers.

You can install Surge protective devices to prevent the occurrence of fire hazards originating from lightning and thunderbolts.

How to Use Protection Devices in a Solar System Set-Up

Using protection devices in a solar system requires fulfillment of the standards of the National Electric Code – NEC. These include:

a. Over-current protection features such as breakers and fuses. These can be optional on the direct current system, but you should always apply them for alternating the current systems.
b. DP circuit breaker – is placed on the main service panel where the wiring from the PV system joins the utility grid.
c. AC disconnect - kept in the area of the main service panel.
d. DC disconnect – it usually comes with most inverters.
e. Net meter socket - one of the requirements by utility firms for recording electricity billings.

f. Ground fault protection – the inverter performs the functions of this feature.
g. A Combiner or Junction Box - used for wire connections beside the array.

Fuse and MCB

Fuse and MCB are among the solar safety devices that you can apply for safeguarding your system.

1. The battery fuse holder for 12V or 24V. It is used as a 12V in-line fuse holder and ideal for being used from controller to battery or controller to load. This fuse holder is designed with waterproof sealing and comes in a red and black finish.
2. MCB means Miniature Circuit Breaker. This device is useful in low voltage DC battery, solar systems, and wind power structures. Examples are single-pole PV circuit breaker, double pole circuit breakers, and Solar or battery MCB box.

CHAPTER ELEVEN

How to Connect a String to an Inverter

Connecting a string to an inverter can impact the current, power, and voltage of a solar system. Every installer needs to understand the stringing processes of a solar array and choose the right inverter for the system, ensuring the system functions properly.

The electricity output from your solar array will be limited to the maximum energy generation of the inverter. If your panels' voltage surpasses what the inverter can carry, it can reduce the lifetime of the inverter. On the same note, if the voltage from the array is too low for the inverter, the system will underperform. The inverter may not function until its **Start Voltage** is reached. Most times, shade can also affect the performance and output of your solar array.

You can use solar software called **Aurora** in managing the stringing process of your solar array.

Things to Consider before Connecting a String to the inverter include

1. Inverter Specifications – this is seen in the product's manufacturer datasheet containing the Maximum direct current input voltage. It also shows the Start Voltage or Minimum voltage of the inverter. This datasheet displays the maximum input current of the inverter, including the MPPT of the device. This tracking system identifies the current and voltage at which the power will be reduced. But the conditions on the solar panels must be consistent to avoid reduced efficiency.
2. Data about the solar panels indicating the short circuit current (I_{sc}) and open-circuit voltage (V_{oc}).

These details about your solar panels are based on the performance of the modules. This is known as Standard Test Conditions (STC). It involves an irradiance of 1000W per square meter and 25 degrees Celsius.

General Rules for Stringing Solar Panels

If you want to have an effective solar system, consider wiring the panels together. This will form an electric circuit through which the current will flow. Wiring the panels to the inverter system will convert electrical energy produced as direct current in the panels to alternating current use in the homes, and excess production will be sent back to the grid.

This process of interconnecting solar accessories for optimal power generation, utilization, and storing is called **Stringing.** Also, each series of solar panels connected is called a **String.** These panels need a **string inverter** and not a microinverter to function correctly. Then, each string inverter is designed with divers voltages for optimum performance.

The basic rules for solar panel stringing include:

a. Make sure that the minimum voltage and maximum voltage are within the range of the inverter system. Don't allow the voltage of the strings to surpass the maximum input voltage of the inverter. Also, it should not go below its **Start or Minimum voltage.**
b. Ensure that the voltage is additive in series strings and the current is additive in parallel strings.
c. Connect strings with similar conditions such as the same azimuth, tilt, irradiance, and orientation. The reason is that any disparity in string conditions will affect your solar system's energy production and efficiency.
d. Strings with different conditions should be connected to other MPPT ports. These strings should be separated into their strings and reconnected to different Maximum Power Point Trafficking (MPPTs) of the inverter.
e. Another advanced strategy is inverter clipping.
f. You can also use Module-Level Power Electronics (MLPE), such as direct current optimizers, software tools, and

microinverters. These microinverters are attached to individual solar panels and make it easier to add more panels to your array in the future.

Types of Solar Panel Wiring

Solar panel wiring could be done in many ways. These stringing processes have a great effect on the voltage and current in the circuitry. They include Series stringing and parallel stringing.

Series Stringing of Solar Panels

Connecting each solar panel to the next in line is the basis of stringing solar panels in series. Solar panels are designed with positive and negative terminals. In this case, the wire from the positive end of a solar panel is connected to the next panel's negative end, and it continues in that sequence.

Each added panel in the series increases the total voltage of the string. However, the current in the string remains constant.

A significant disadvantage of choosing series wiring is that if a panel is shaded, it automatically reduces the current through the whole string. The current remains the same throughout the string, the current is lowered to that of the shaded panel with the lowest current.

Parallel Stringing of Solar Panels

In parallel stringing of solar panels, all the panels' negative ends are connected to a single wire, while the positive ends of all the panels are connected to another wire. In this system, each added panel increases the amperage or current of the circuit. But the voltage of the circuit remains constant and equal to the voltage of each panel.

The advantage of stringing solar panels in parallel is that when one panel is covered by shades, the other panels will function separately, and the voltage of the entire array will not be lowered in any way.

CHAPTER TWELVE

Analyzing the Main Service Panel

In a solar power array, the pane is not the only part that makes the system thick. There are several components of the entire system, and each of these parts is from different brands. Therefore, the main service panel includes solar panels, batteries, racking systems, and inverters.

1. Solar Panels

Solar panels are the most visible part of a solar system and are usually associated with it. A sight of solar panels on the roofs of houses will tell you who is using a solar system or not.

These panels generate electricity in the form of direct current when sunlight hits and stimulates built-in electrons moving through solar cells in your solar panels. It is the sunlight that produces electricity and not the heat from the sun. On the other hand, if your panels are overheated, they become less efficient than overheating in computer systems.

Therefore, ensure that your choice panels can withstand arid conditions, including harsh weather elements in your region, for at least the net twenty-five years.

Solar panels are produced with different technologies such as monocrystalline panels and polycrystalline panels.

Monocrystalline panels – are made of special large crystals that are darker in color and beautiful. Due to the way the product is designed aesthetically, you may not see the corners. These panels are seen to be superior to the polycrystalline ones and produce higher peak efficiency. The reason is that large crystal cells quickly

absorb sunlight. The product is more readily available than polycrystalline panels.

Polycrystalline panels – are made of several smaller crystal particles that could be light or dark blue. It comes in a variation of textures some patches lighter than others.

Choose a good brand of solar panels before buying. Some of the products that may last for you include Hyundai, Canadian Solar, Phono & Trina, and jinko. Other brands with more extended warranty periods and regarded as superior to the former ones include SunPower, Q-Cells, and LG.

However, concentrate on the quality of the photovoltaic panel, the manufacturer’s trustworthiness, and the product's performance in the long run.

2. Batteries

Excess power produced during sun peak hours in the day is stored in the batteries used at night. Also, extra energy generated on sunny days is used on cloudy days when the weather is not friendly.

The choice of battery for your solar array depends on your feed-in-tariff and your household's energy needs.

3. Racking System

The racking system or mount is another crucial component of a solar array. Most brands that provide solar panels and accessories use high-quality materials in their products considering the lifetime and warranty that usually accompany solar panels.

4. Inverters

To power your home appliances, you need to install inverters to convert the direct current generated by solar panels into 240V

alternating current use in your apartment. It operates throughout the lifetime of your solar system.

Most times, it could be the only equipment in your solar array that develops faults. The warranty for inverters is usually ten years. Purchase high-quality inverters that can be serviced easily. Examples of these inverters include ABB, SolarEdge, Fronius, and Sungrow.

Types of Inverter Technology

There are two types of inverters, such as microinverters and string inverters. Microinverters are installed behind each panel to enable the panels' power to form separately from each other.

However, in a string inverter system, when shading occurs on a solar panel, all the panels' performances are affected. But with microinverters, this issue does not happen. Microinverters are known as power optimizers in the solar system.

A string inverter is installed onto a wall in a shaded area. It converts the power from a string of panels for residential systems into alternating current use for your home or business.

CHAPTER THIRTEEN

How to Connect Inverter to MSP

Inverters are used for connecting a DC electricity of 12 V or 24 V into a 230 V alternating current. To convert 12 V DC you need a SinePower MSP 162 or MSP 352. Also, to convert 24 V DC electricity, you need a SinePower MSP 164 or MSP 354. You can cool the MSP devices with a load and temperature-based fan.

However, inverters MSP 162 and MSP 164 will give an output of 150 Watts while inverters MSP 352 and MSP 354 provides 350 Watts.

Connecting an inverter to MSP is possible but only extends the connection line with cables that have a cross-section equal to or more than that of the connection line. It is not advisable to reverse the polarity because that will cause a great spark to melt the internal fuses. Note: consult a qualified electrician to replace the fuses.

How to connect external switches

You can connect an external switch to an inverter with a connection cable using a Western telephone jack. Check how the PIN is configured on the plug for the connection cable.

Now, cut the connection cable to suitable sizes following the wiring diagrams. Another method is to consult a professional to connect the device for you.

After this step, connect the external switch with the connection cable on the remote port.

CHAPTER FOURTEEN

What are the Sizes of Cables to Use?

You need to use a solar cable to string together your solar hardware. Most solar panels come with standard cables, but you may need to buy your wires. PV cables are large cables with multiple wires in a protective jacket. You may need a different cable, depending on the solar system. Solar cables may be 4 mm or 6mm, which could be thicker and help transmit higher voltage.

You may also notice some differences in the types of solar cables for direct current and alternating current.

How to Determine the Sizes of cables

To determine the right sizes of cables for your solar panels, you need to understand some terms associated with solar wires. One of the most common sizes of PV wires is called the American Wire Gauge (AWG). A low AWG covers many areas with reduced voltage drops.

In solar panel wiring, the size of solar panel cables is necessary since it can affect the whole solar array's performance. Purchasing a smaller cable than the recommended size can lead to unexplainable drops in voltage across the wires. This will lead to a loss of power. Also, undersized cables can cause a surge in power, leading to a fire in the system. Fire eruption on rooftops resulting from using the wrong sizes of cables for solar panels can spread to other parts of the house.

But suppose you have a solar cable that is not big enough to carry the current from the PV panel. In that case, the resistance can lead to less amount of electrical energy being transferred as the circuit is tiny and may not contain much flow of power.

The sizes of solar cables are determined using American Wire Gauges, as I said earlier. If you are using a cable with a lesser gauge (AWG) number,

you may experience lesser resistance, and the voltage from the solar panels will be released quickly. Each solar cable has different gauge sizes that can affect the price of the various wires. These gauge sizes come with their AMP rating. This is the maximum amount of AMP that safely travels through the cable.

Different cables can allow and transmit a certain amount of voltage and amperage. If you can understand and analyze the wire charts, you can quickly determine the right size of cable you may need. You can connect the photovoltaic panels to the main inverter with different wires while the inverter is connected to the batteries. The batteries will also be connected to your battery bank, while the inverter will be connected to the grid directly.

You can determine the sizes of cables using two methods:

1. **Calculating the Voltage Drop Index (VDI) of the Solar Array –** some information from the manufacturer that can help you calculate the voltage drop index (VDI) of the solar system includes total amperage, voltage drop percentage, and length of the cable in one direction. The calculation of VDI is measured in feet, and the formula is:

Amperage x Feet/percentage of voltage drop

2. **Calculating Size Using VDI –** calculating each cable's size in the solar array is possible using a VDI. However, the following chart will help you to discover the size you need for the application.

S/N	Voltage Drop Index	Gauge
1.	1	# 16
2.	2	# 14
3.	3	# 12
4.	5	# 10
5.	8	# 8
6.	12	# 6
7.	20	# 4

8.	34	# 2
9.	49	# 1/0
10.	62	# 2/0
11.	78	# 3/0
12.	99	# 4/0

Types & Sizes of Solar Cables

There are two types of solar cables such as direct current cables and alternating current cables. The most essential cable is DC cables since the electricity generated from solar panels and used at homes is direct current electricity. Some solar systems are designed with DC cables that can be used with proper connectors. The renowned sizes of cables for direct current include **6 mm, 4 mm, and 2.5 mm.**

You can use a smaller or larger cable, but this depends on the solar system's size and the corresponding electricity produced. Use the strings in the main connector box to connect the positive and negative cables. DC cables are connected in external locations such as the top of roofs, including other areas where the solar panels are installed. Ensure that you separate positive and negative wires to avoid accidents.

Connecting Solar Cables

Solar cables are connected using a positive cable, which is a red cable for transmitting electricity. Another one is a negative cable, which is blue. These cables connect to the main generator box of the inverter and solar system. If you wrap smaller single-wire cables in insulation, they can be sufficient for energy transmission.

Installers rarely use AC cables in solar system installation. But they are used for connecting the central solar inverter to the electricity grid of your apartment. Solar systems use five-core alternating current cables. In this case, three wires are used for the phases conveying the current. A wire is used for keeping electric current away from the device, while another wire is used for safety or grounding to connect the solar system to the ground.

You can also use three-core cables in connecting your solar panels, depending on the size of the array. But this procedure is not the same in all regions since regulations for installing solar panels and cables could differ from place to place.

CHAPTER FIFTEEN

The Installation Processes of Solar Systems

As I have said earlier, a solar system comprises solar panels, an inverter, a computerized controller, and a mounting system. The best place for installing solar panels is the roof for better exposure to sunlight. Also, you can install it on the ground in an area with proper access to sunlight.

Here are the processes for installing solar panels:

a. Erect the scaffolding to ensure safety during the whole process of installation on the roof.
b. Set up the solar panel mounts – with this, you can support the solar panels' base. Ensure that you tilt the angle between 18 degrees to 36 degrees for better exposure to sunlight.
c. After installing the mounts, set up your photovoltaic panels and set up your panels on the mounting structure. Ensure that you tighten all the screws to make it stable on the roof.
d. Wire the PV panels – After setting up the panels, the next step is the unit's electrical wiring. MC4 connectors designed for different types of solar panels are used in the wiring process. But disconnect the electricity supply to your apartment first during the process of wiring.
e. Set up the Inverter – connect the solar inverter to the solar system. It is positioned beside the main panel. You may choose to place it indoors or outdoors but in a more relaxed place. If you want to keep the inverter indoors, consider places like the garage, where it can receive proper ventilation.
f. Connect the inverter to the battery – connecting the inverter to the battery will create a backup for your system and provide energy for your home during cloudy days.

g. Begin to generate electricity by connecting the inverter to the consumer unit. After generating the electrical current, you can use a generation meter to access the amount of electricity produced by the solar panels. A computer or other devices could be used to check the performance output of your solar array. You can determine the volume of electricity produced at various times and know the convenient time to use an electric cooker.

h. Test the solar system by switching it on – after completing the solar system installation; the next step is to test the unit.

Electrical Installations and Connections

A solar system is designed with electrical installations and connections before you can use the system optimally. These include

1. The conduit conveys power from the panels to the house, but it should be buried. Then, construct a platform using concrete pillars in 4 by 4 dimensions.
2. Set up the panels after constructing the platform.
3. Determine the accurate angle of the panels using meteorological data. Then, elevate the back legs and make them secure.
4. Wire the solar panels and join them at a fuse combiner box or junction connector.
5. After assembling, angling, and wiring the solar system, you can then connect the outer wires to the interior control panels. Then, the solar breaker will be connected to a circuit breaker disconnect. The electrical power will flow from the disconnect to a charge controller and proceed to a battery bank for storage. When the energy is needed in the home, it will flow from the battery to the circuit breaker, disconnect and proceed to the inverter.

6. Run the cables from the solar panels to your apartment through the conduit. Then, connect the wires to the nylon thread for easy threading and pull through the conduit to inverter panels. Join the cables at the fuse combiner box at the lower part of the solar array. But firstly, connect the green wires to the grounding strip, the red cables to the photovoltaic out positive terminal block, while the black cables will be connected to the photovoltaic out negative terminal block
7. Conclude the exterior work by tapping a grounding rod into the ground close to the array. The longer rod will extend above the earth by six inches. Then, connect the copper earthing wire from the rod to the fuse box. Also, run this wire from the solar panels to the fuse box.

8. Now that you have connected the grounding wire run the electrical wires properly inside the system. The cables should be linked from the array to the inverter panel disconnect. Let the red cable be joined to the positive terminal. Also, the green cable, which is a grounding cable, should be hooked to the grounding terminal. Then, the black wire should be joined to the negative terminal.
9. The battery bank should be placed on top of the new control panel. But run the conduit through the ceiling into the inverter panel. Then, connect two-heavy-duty battery cables into the panel disconnect. Let the other ends of the wires be joined to the batteries. Ensure that the batteries are installed by alternating a positive terminal to a negative terminal in series. Secure the batteries before conducting the final test.

CHAPTER SIXTEEN

How to Rack Up the Solar System

Solar racking is used to fix the panels onto the roofs safely. It is also used to hold them securely on the ground for solar panels mounted on the ground. Solar racking is made of aluminum materials and useful for installing panels on the roof of apartments.

The components of a solar racking include clamps, mounts, flashings, and rails.

Landscape and Portrait

Solar panels can be positioned in a landscape orientation or portrait orientation. These orientations do not affect the number of panels that will be installed. Also, it does not affect the efficiency of the array on the ground or a rooftop. But the configuration of your roof determines the size of your solar array and maximum exposure to sunlight.

Some homeowners can decide to use both orientations on their homes at the same time. In this case, the installers can use a standard rooftop racking system. This is highly optimized for vertical mounting systems.

But if you decide to use horizontal orientation, you may add more rows of solar panels to your array.

Rails and Rafters

Solar racking is an essential aspect of solar systems. After installation, you can select the rails. But determining where the roof supports are and ensure that the roof can carry additional weights.

The rafters on your roofs are spaced up to sixteen inches, while the standoffs are spaced forty-eight inches. Consult a professional if you notice

your roof is not capable of holding the panels.

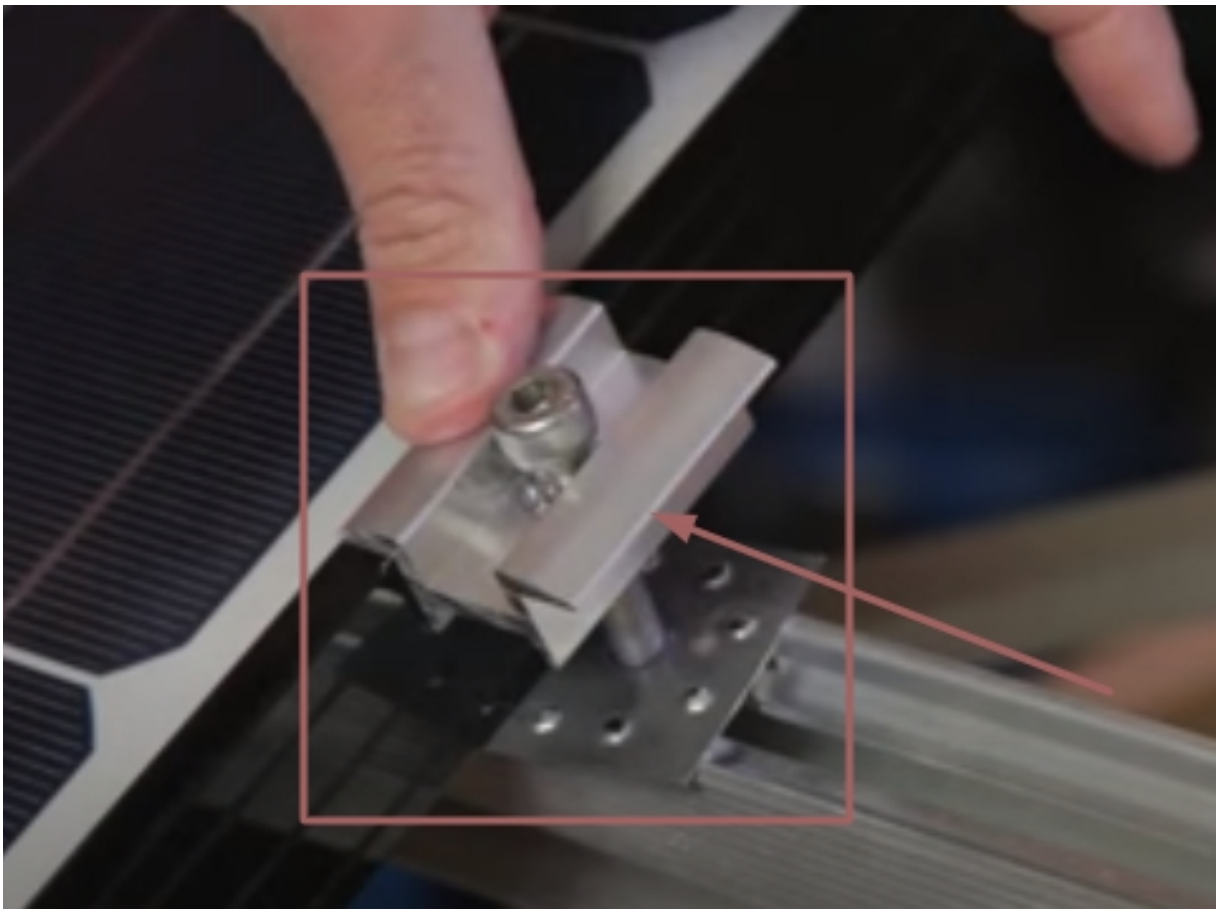
Before you can select the right rail, you should consider the panels' width in portrait configuration. Your solar panels have an articulated width of 4 x 40 inches in dimensions, giving you 160 inches. However, every module should be connected to two rails.

In terms of rails, longer rails are preferable to shorter rails. The rails should not be longer than 160 inches. If you notice that the rail is longer than the required dimension after installation, cut off the excess for a perfect fitting.

Using Standoff

Using standoff mounting entails the method of installing solar panels on sloped roofs. Connecting standoffs do this to the roof's structural system for supporting and holding the rails. These solar panels are mounted on top of the rails. The standoff creates a gap of 3 inches or 5 inches between the roof and solar panels. This space allows a free flow of air between the top and solar panels to cool off the devices, especially in hot temperatures.

Mid Clamp and End Clamp in Solar Systems



Installing Clamps on Solar Panels

Depending on your choice, you can use mid-clamps or end clamps for holding your solar panels. These clamps are made with aluminum materials for positioning and installing your solar panels properly onto the roof.

Features of Mid Clamps for Solar Panels

a. It is designed with accurate dimensions.
b. Mid clamps are easy to install.
c. It is resistant to corrosion.

Features of End Clamps for Solar Panels

a. The installation process is easy.
b. It comes with precise dimensions.
c. It is resistant to abrasion or corrosion.

CHAPTER SEVENTEEN

What is Racking Websites in Solar System Set Up?

Racking is an essential aspect of a solar system set up. It is fastened onto the support of your roof. Then, your solar panels are mounted on it.

You may see varieties of racking systems on the market, such as Schletter, SunLock, Radiant, TITAN Solar, Reddot, Hopergy, and Clenergy.

The racking system helps you in mounting your solar panels faster and more securely. It can also be anchored to the ground for holding an extensive array of solar panels.

CHAPTER EIGHTEEN

Summary of Solar System Installation Processes

Solar system installation processes could be summarized as follows:

1. Begin by setting up the scaffolding.
2. Then, attach solar panel mounts.
3. Connect your solar panels.
4. Wire the photovoltaic panels.
5. Attach your inverter system.
6. Connect the solar battery and solar inverter.
7. Attach the inverter to the consumer unit.
8. Then, switch on and test your solar panels.

Determining the Size of the Required System

To determine how many solar panels you need, multiply your household's hourly energy needs by your area's peak sunlight hours. Then, divide the figure by the wattage of a panel.

You can use a low wattage such as 150 Watts and a high Wattage such as 370 Watts to establish a range at this stage.

Assessing the Roof

Assess your roof before mounting solar panels to know if the top can carry your panels' weight. Here are ways to access your roof before installing solar panels:

a. Check the condition of your roof.
b. What direction is the slope of your roof facing?
c. What degree of weight can your roof handle?
d. If rains fall, where will the water go?

These are some of the ways to assess a roof before installing your solar panels.

How to Choose a Brand of Solar Panels

Due to discrepancies in solar panels' features and capacities, you need to make a choice carefully. Here are various reasons to consider before picking a solar panel:

a. Select a suitable brand based on the efficiency of such a panel.
b. If you want an environmental-friendly solar panel, choose polycrystalline panels.
c. For cheap solar panels, consider thin-film options.
d. Amorphous solar panels are made for smaller apartments.
e. Research about manufacturers of solar panels.
f. If you live in low wind areas, decide to buy a ballasted mount.
g. To secure your panels tightly, go for a mechanically-connected mount.
h. Use fixed mounts if you cannot install your solar panels on the roof.
i. Consider your electrical needs before buying solar panels.
j. The type of apartment you are living in will determine the kind of solar panel to buy.
k. Solar panel installation attracts rebates. Check to know if you will benefit from government rebates before buying panels.

Choosing an Inverter

Before you connect an inverter to your solar system, ensure that it's rating in Watts corresponds to your solar system. If you can size an inverter properly, it will guarantee optimum performance for your solar array. On this note, if your solar array can generate 1000 watts, you need an inverter with 1000 watts capacity.

MSP Upgrade

To upgrade an existing solar system array, you should add more panels using your inverter system. Simply get a new and bigger inverter and add more PV panels to it. Install the new solar panels close to the first ones.

Selecting a Circuit Breaker

Selecting a circuit breaker is determined by the features of electrical installations, the loads on the system, the environment, including the nature of telecommunication systems involved, also, the need for a remote-control system in managing solar installations.

Therefore, choosing a circuit breaker is done based on:

a. The voltage, AC, or DC of the installation at hand.
b. Functional requirements for remote control and indication, including supporting contacts, connection, and secondary tripping coils.
c. Assumed short-circuit voltage during installation.
d. Features of loads such as fluorescent lighting, LV/LV transformers, motors, and LED lighting.
e. The ambient temperature of the environment, weather conditions, and switchboard enclosure.
f. Co-operation with downstream and upstream device selectivity.
g. Regulations on installation, including protection against electric shock and thermal effect.

Choosing the Size of Cables

If you install commercial solar panels that can generate more than fifty watts of power, you need 10 gauges (AWG) cables. With this structure, you can produce up to thirty amps of current to flow from a single panel. When you combine multiple panels in parallel connection, a set of 3 to 88 AWG combiner wire is needed. With these cables, you can quickly transfer the electrical energy generated to a charge controller.

Understanding the Mechanical Requirements

The mechanical requirements of solar power systems include the solar panels, metal racks, rooftops, mounts, clamps, ballasts, and an engineer that can design the system for optimal profitability.

How to Purchase the Items

You can purchase your solar systems using the following procedures:

1. Purchasing through the recommendations of family and friends.
2. Check the duration of the manufacturer's warranty.
3. Have feasible price expectations.
4. Decide on the type of solar panels you want to buy.
5. Look out for some certifications that come with the solar panel.
6. Decide on how to mount the panels.
7. Check the efficiency of the inverter system.
8. Consult the professionals to get some solar quotes.

CONCLUSION

During nighttime hours and cloudy days, it is difficult for the unit to generate enough power to sustain your household. But on sunny days, your solar panels can produce the necessary energy for your appliances and other utilities.

Due to this imbalance in power supply, battery storage is necessary, especially if your home, car, RV, or van is connected to the general grid. It is impossible to power your small home using the general grid.

This book has detailed information on how to set up your solar system from scratch. If you can study this guide, you can stand toe-to-toe with anyone who claims that he is a professional in the industry. It also explained several terminologies that can give you clues to ask questions if you engage the installer's services.